Reproduction and Ecology of the Longnose Killifish

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Almost nothing is known about the reproductive behavior and early development of the longnose killifish, *Fundulus similis* (Baird and Girard). Breder and Rosen (1966) omitted the species in their comprehensive survey of literature on reproduction of fishes. Springer and Woodburn (1960) discussed courtship displayed by this fish in captivity. Simpson and Gunter (1956) noted that spawning occurred in the shallows of Copano Bay, Texas, during July but offered little descriptive data; no eggs were recovered after the presumed spawning had taken place. Male breeding colors were described by Joseph and Yerger (1956) and later by Springer and Woodburn (1960).

The ecology of *F. similis* in Tampa Bay, Florida, is incompletely known. Springer and Woodburn (1960) summarized their own and other ecological data. The junior author has contributed additional data on life history from field collections of 1962 to supplement knowledge of the local distribution, seasonal occurrence, spawning, growth, and environmental tolerances of the species.

Materials and Methods

Fish were preserved in a neutralized 10 per cent formalin solution. Field specimens were measured to the nearest millimeter and aquarium specimens to the nearest 0.1 millimeter of standard and total lengths. Weights were recorded to the nearest 0.01 gram on a triple-beam chemical balance.

A breeding pair of *Fundulus similis*, a large gravid female (111.6 mm SL) and a mature male (46.3 mm), collected by seine in Boca Ciega Bay near Three Palms Point on March 30, 1967, was placed with other fish in a 30-gallon tank containing filtered sea water (see Table 1). When courtship began, the other occupants of the tank were removed; the parents were also removed after spawning to prevent them from eating the eggs.

An inspection of egg masses on the third day of development indicated that conditions in the original aquarium were not optimal for growth and survival. A number of eggs were then transferred

to a 1,000-ml beaker containing dilute sea water (Table 1), where they remained until they hatched or were preserved.

Newly hatched fry were transferred to a 30 gallon aquarium and maintained on a diet of live brine shrimp and dry food (Tetramarin) [Reference to trade names in this publication does not imply endorsement of commercial products]. Water quality was similar

TABLE 1

Water quality in laboratory experiments

Laboratory equipment	Salinity (%)	Temperature (°C)	Oxygen (ppm)	pH
Spawning aquarium	34.5	24.2	5.5	8.2
Hatching beaker	19.0	24.0-26.9	5.7-6.2	8.1
Rearing aquarium	20.4-22.8	24.0-26.9	5.7-6.2	8.1

to that in the beaker. With the exception of salinity, the water conditions resembled those in the original aquarium where spawning occurred (Table 1). Aquariums were supplied with air and contained silica sand, subsand filters, coral rocks, and plastic plants.

Ecological studies consisted of monthly and bimonthly collections of fish and water quality data at 18 sampling sites in 1962 throughout Tampa Bay (Fig. 1). All specimens were collected with a 70-ft nylon beach seine having a body and bag of ½-inch stretch mesh. A 30-ft minnow seine was used at a few stations where bottom conditions did not permit the use of the larger net.

Water temperature was measured in the field with a standard mercury thermometer to the nearest O.1 C. A modified Van Dorn sampling bottle (Van Dorn, 1957) was used to collect water samples. Salinity in parts per thousand was determined through titration by the Mohr-Knudsen method (Knudsen, 1901). Oxygen was determined by the spectrophotometric method of Austin (1949). The pH determinations were made with a Beckman pH meter.

COURTSHIP AND SPAWNING

Courtship in the aquarium began shortly after the captive pair was introduced on March 30, 1967. (Fig. 2). This ritual was followed by five successive spawnings, and ceased after about 2 hours (1630-1830). Courtship by the male was centered about the head

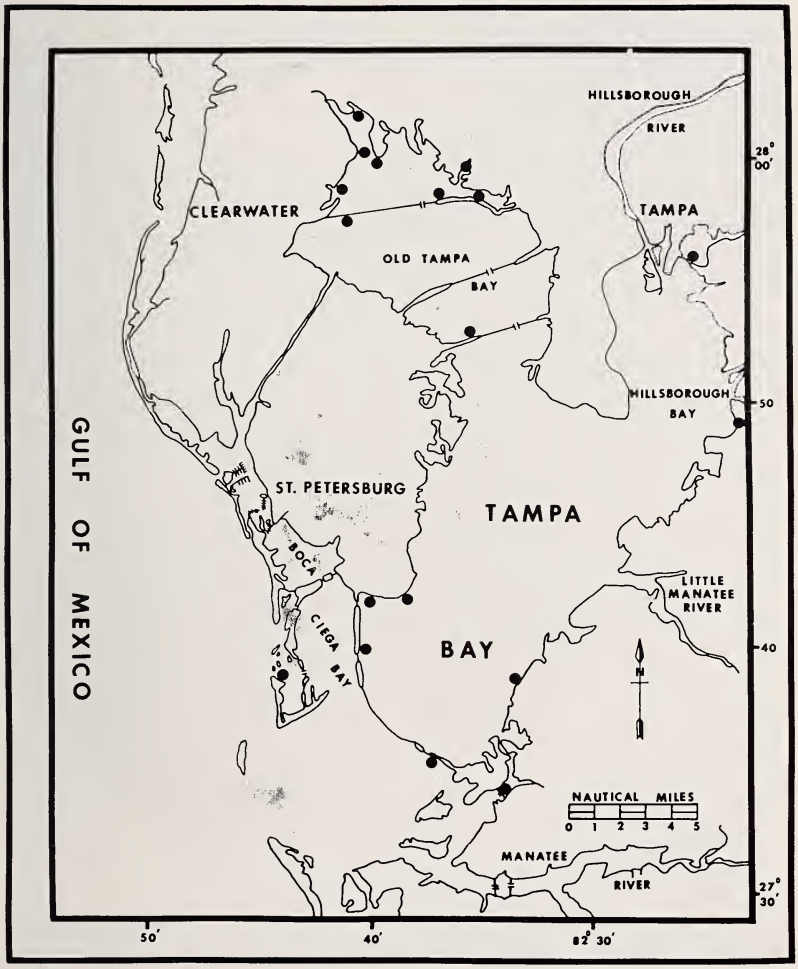
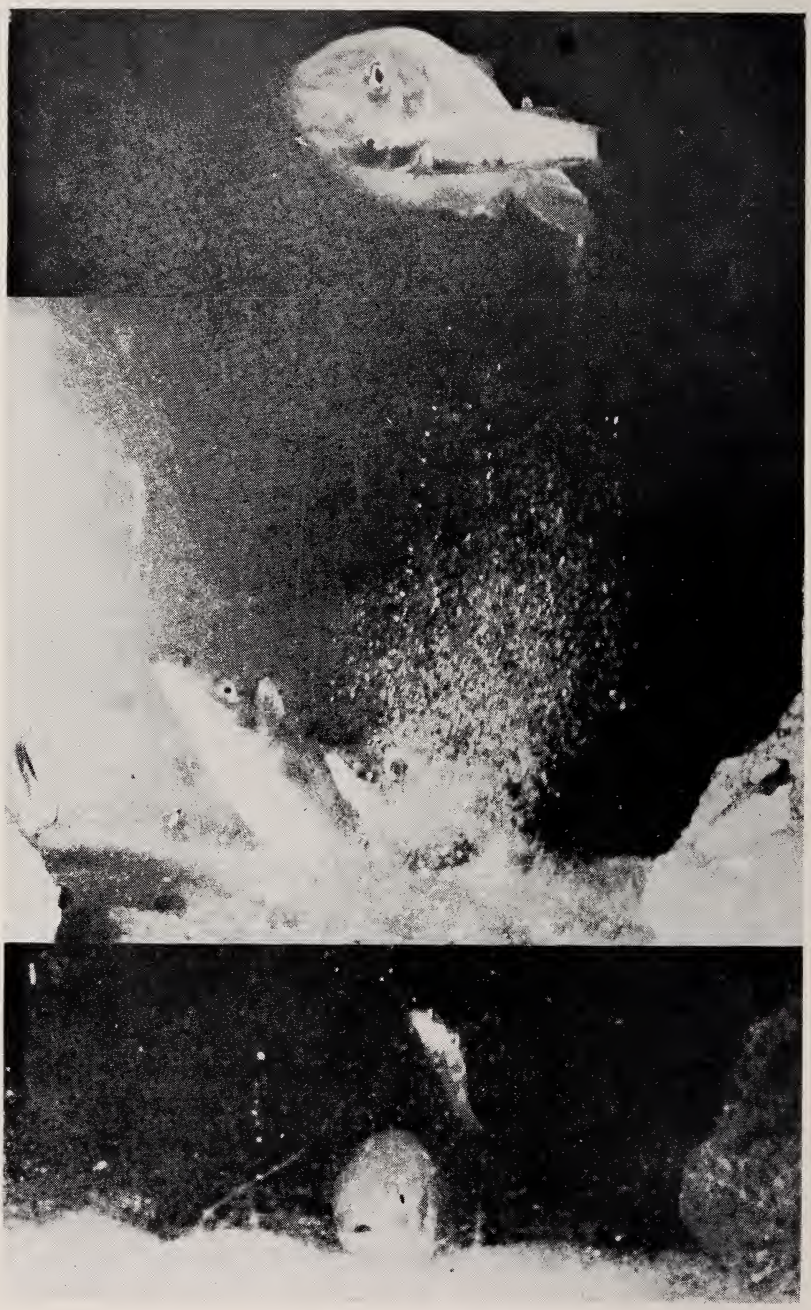


Fig. 1. Map of Tampa Bay, Florida, showing sampling stations where *Fundulus similis* was caught in 1962.

of his much larger mate. His frantic swimming and vibrant color changes often halted the female. She tended to remain nearly stationary but occasionally darted off in a new direction, and once moved to the bottom where she appeared to be testing the suitability of the substrate. Three swimming patterns were followed incessantly by the male: (1) tight figure-eight, passing beneath the female's snout, (2) broad circle, coursing counterclockwise, and



(3) elongate oval, following the same course as the preceding, but often passing close enough to the sides of the female's body to brush her.

As the tempo of courtship increased, forays to the vent resulted in the male's nipping and brushing the anal fin and region of the ovipositor. While he followed the oval or circular course, the male tended to erect his vertical fins and display exceptional colors. Transient dark zones appeared on the snout and behind the eye. Flanks of the body became violet and green. The normally prominent series of dark vertical bars characteristic of the species were indistinct at this time. Immediately before spawning, the male passed very close to the flanks of his mate and brushed them. The circular movements had become a compressed oval.

In response to the antics of her mate, the female suddenly interrupted her forward movement as though faltering. Next, she darted forward an inch or two only to reverse this movement by backing up an equal distance. These opposing movements continued for several moments, but gradually became more restricted until they constituted an anterior-posterior rocking action. At the peak of this activity, the female suddenly became almost motionless but quivering, and she approached the substrate to begin deposition of the eggs.

The female suddenly swam to a position just above the selected spot, where she hovered for a moment. A sudden wriggling movement created a furrow in the sand where the first eggs were extruded. As she moved forward in the sand, deposition of more eggs was accompanied by flips of the caudal fin which sent sand flying (Fig. 2b) and served to cover the eggs. The male was often difficult to follow at the time of fertilization because he appeared to parallel the female or follow closely during the height of the sand flinging. On one occasion he swam or rode on her back near the dorsal fin as the eggs were being deposited. After completion of spawning the female remained near the covered eggs (Fig. 2c). We found no well developed "contact organs" such as those described by Myers (1931) and others for males of the tribe Fundulini; the exact method of fertilization was not observed.

Fig. 2. Courtship and spawning activity of *Fundulus similis*. From top to bottom, (a) male executes figure-eight movement beneath snout of female; (b) spawning act: female deposits eggs in sand accompanied by male; (c) spawning is completed.

EMBRYONIC DEVELOPMENT

Five distinct clusters of eggs, each deposited at a different time and location, were removed for embryonic study. They were covered to a depth of ½ to ¾ inch with sand. A total of 457 eggs was counted. Only 35 healthy eggs were selected for future study,

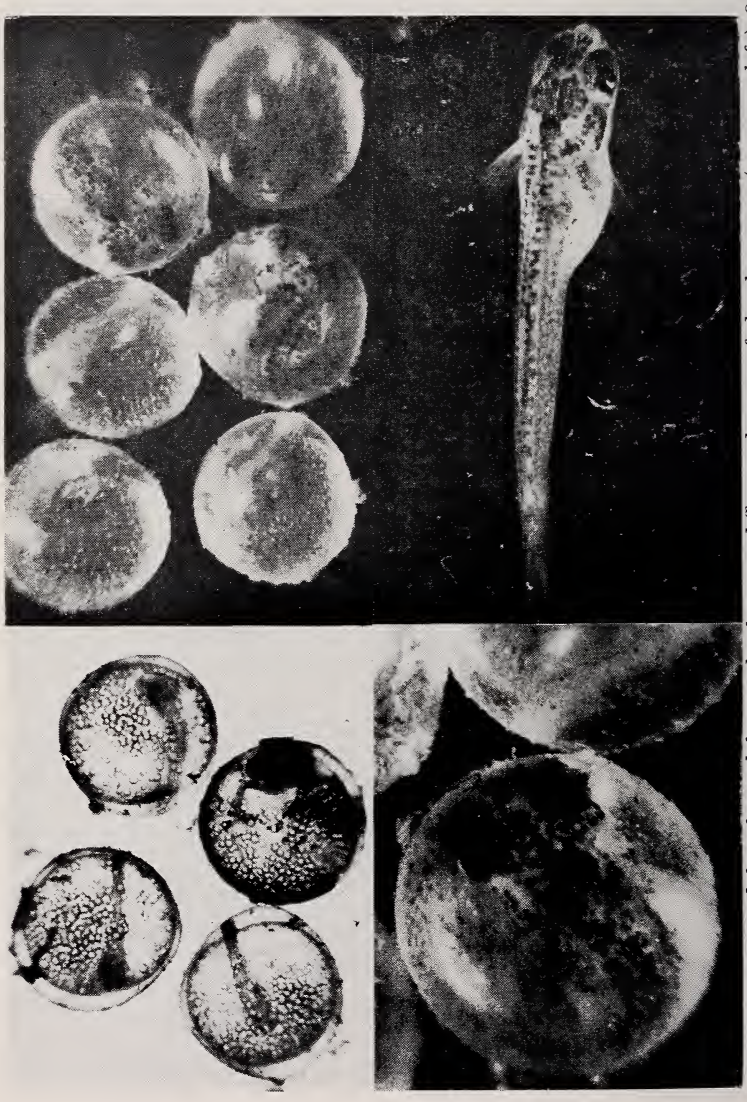


Fig. 3. Eggs and fry of *Fundulus similis* showing different degrees of development: (a, upper left) 8 days old; (b, upper right) 11 days old; (c, lower left) 12 days old, immediately before hatching; (d, lower right) newly hatched fry.

since many were infested with parasitic worms or fungus on the third day of development.

Eggs were 2.8 to 2.9 mm diameter and spherical, but somewhat flattened at the poles. Yolks were oily and non-granular (Fig. 3).

TABLE 2

Stages of embryonic development in *F. similis*. Stages are those of Lagler, Bardach, and Miller (1962).

Age (hours)	Stage	Stage and description
0-2	1,2	Unfertilized and newly fertilized eggs.
2-4	3	Two-celled stage.
15-17	11,12	Late blastula and early gastrula.
22-24	13,14	Middle gastrula and late gastrula.
39-41	15,16	Primitive pit-stage and neural tube stage.
44-46	16,17,18	Neural tube to 8-10 somite stages.
64-66	20	Twenty-five or more somites; heart formed and pulsating; lens and optic cup formed.
66-68	21	Embryo twitching inside egg; twenty-eight or more somites.
88-90	22,23	Circulation clearly established; blood has color; olfactory placode present; forebrain thickening; midbrain and cerebellum well differentiated.
112-114	22,23	Pectoral fin bud forming.
118-120	23	Retina heavily pigmented.
139-141	23,24	Pectoral fin bud present; otoliths formed; little if any pigment inside body or near body surface.
160-162	26	Caudal fin being delimited; semicircular canals formed; eyes not moving; eye with refractive layer; black pigment on top of head, and in two principal rows along sides of body.
189-191	28,29	Peritoneal walls pigmented; olfactory bulbs formed; pectoral fin mobile; yolk mass occupies about ⅔ inner mass of egg.
207-209	30	Caudal rays formed; heart with bulbous atrial ventricular portions; yolk mass occupies about ⅓ of egg mass.
231-233	31	Lower jaw well formed and moving; gill opening and mouth operating in mock respiratory movements; eyes moving; liver primordium present; yolk occupies about ¼ of inner mass of egg.
258-260	32,33	First embryos hatched; some yolk still present; pigmentation extended to sides of body.
282-310	—	All eggs except two hatched.
482-484	—	Last two eggs hatched.

Detailed embryonic studies were not made because development closely resembled that of other species in the same genus. Development of several stages is summarized for the most advanced embryos (Table 2). The stages follow those given by Lagler, Bardach, and Miller (1962) for *Fundulus heteroclitus*. Hatching time at temperatures of 75.2 to 80.4 F (24 to 26.9 C) varied from 11 to 13 days for most eggs, but two did not hatch until the 20th day.

GROWTH RATE IN AQUARIUMS

Length measurements and weights of aquarium-reared juveniles indicate that growth was rapid (Table 3). Fry measured 7.3 mm

TABLE 3

Development of aquarium-reared specimens of *F. Similis*. One fish selected at random was weighed and measured for each date listed.

Date (1967)		Weight (grams)	Standard Length (mm)	Total Length (mm)
April	13	0.01	7.3	9.0
	19	0.02	11.1	14.2
	26	0.07	16.0	19.8
May	3	0.11	18.3	23.0
	10	0.25	23.7	28.9
	17	0.36	26.7	32.9
	23	0.41	28.2	34.8
	31	0.46	29.0	35.7
June	7	0.43	29.8	36.3
	14	0.50	30.4	36.6

SL at hatching. Adult form was reached in the 6th or 7th week after hatching, and specimens approached the size of the male used in the experiment after about 10 weeks.

ECOLOGY AND DISTRIBUTION

Fundulus similis is the most abundant cyprinodont in Tampa Bay. A total of 4,762 specimens were collected at 18 sampling sites during monthly and bimonthly seine sampling in 1962 (Fig. 1 and Table 4). Although the species was caught throughout Tampa Bay,

TABLE 4

Frequency distribution of *F. similis* by standard lengths in Tampa Bay, 1962

Midclass (mm)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
15	1	—	—	9	4	1	—	—	—	3	7	—	
20	1	1	1	49	19	28	—	—	—	27	56	8	
25	1	—	4	83	28	54	5	—	4	64	67	22	
30	9	2	4	45	47	55	75	8	6	51	102	25	
35	4	2	14	14	112	34	234	49	16	45	100	40	
40	7	7	31	16	126	19	198	70	58	27	106	58	
45	3	8	61	9	35	8	100	93	76	32	84	71	
50	2	10	31	9	23	2	47	75	73	49	44	36	
55	3	6	21	10	22	6	30	40	47	47	22	49	
60	4	5	16	5	11	8	9	26	30	44	23	43	
65	10	7	14	5	11	6	8	20	28	37	17	28	
70	10	10	18	12	15	6	15	17	16	27	12	20	
75	9	6	13	1	7	7	14	11	5	14	10	20	
80	8	8	19	2	11	6	22	15	2	11	7	13	
85	4	6	6	1	12	4	15	13	2	26	1	5	
90	11	2	2	2	8	5	12	4	3	18	—	1	
95	3	1	3	—	2	4	12	6	2	12	—	1	
100	2	—	1	—	5	3	16	2	—	9	—	—	
105	2	—	—	—	2	3	9	—	3	9	—	2	
110	—	—	—	—	—	1	1	—	—	—	—	—	
115	—	—	—	—	—	—	—	—	1	—	—	—	
Total	94	81	259	272	500	260	822	450	372	552	658	442	4762
Average standard length (mm)	64.7	61.1	54.5	33.2	43.8	40.4	48.2	51.6	51.5	57.9	40.0	49.4	

over 50 per cent of the catch came from Old Tampa Bay, the Hillsborough Bay area, and central Tampa Bay.

The species is extremely hardy and can adapt to a wide range of ecological conditions. It was found at salinities of 0.09-35.35 o/oo and at water temperatures of 9.6-33.3 C. Even though the species is euryhaline, catches were largest in salinities of about 19 to 30 o/oo. In December 1962, a record freeze caused extensive fish mortalities in the Tampa Bay area, but *F. similis* was not affected. It occurred in greatest numbers from 23-25 C.

Juveniles and adults both prefer a soft sandy-silt bottom and an open beach usually free of attached sea grasses. Bottom composition seems to be important since the fish burrow rapidly in soft bottom to escape predation. Possibly one reason why the species is seldom caught along the Gulf beaches is that it avoids the relatively hard shelly sand bottom customarily found in these areas.

Specimens from the middle and upper Bay were generally more intensely colored and larger than those from the lower Bay. During breeding, males in the middle and upper Bay became almost solid black but the color of the females remained generally unchanged.

Breeding probably extended year round, although spawning peaked in the spring and late fall and was reduced from July through September (see length distributions in Table 4). Water temperature greater than 30 C during the summer may have depressed spawning.

Growth was rapid but because of prolonged spawning and overlapping size groups and possible sex differences, a growth curve was not determined. The monthly length distributions of Table 4 do give some indication of the growth of small fish. Compare, for example, the abundance of small fish in April-June with their relative scarcity in July-September. Again, small fish were more plentiful in October-December than in January-March.

ACKNOWLEDGMENTS

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